CERTIFICATE

I, Tadashi UEDA, residing at 1994-152, Hazama-cho, Hachioji-shi Tokyo 193-0941 Japan, hereby certify that I am the translator of the attached document, namely a Certified Copy of Japanese Patent Application No. 2002-316081 and certify that the following is a true translation to the best of my knowledge and belief.

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[Name of Document] Drawings 1

[Name of Document] Abstract 1

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[Claims]

[Claim 1] A display device comprising: a first display means having a display surface on the front surface thereof; a second display means having a display surface on the rear surface thereof; and a common illumination means interposed between the first display means and the second display means, for illuminating both the first display means and the second display means with light,

wherein the illumination means comprises a light-guiding member including a first light-emitting surface opposed to the first display means and a second light-emitting surface opposed to the second display means, and

wherein the second light-emitting surface of the light-guiding member and the second display means have a transflection means interposed therebetween.

[Claim 2] The display device according to Claim 1, wherein the display area of the first display means extends so as to overlap two-dimensionally with the display area of the second display means and an area lying outside the latter display area.

[Claim 3] The display device according to Claim 2, wherein the transflection means has different optical characteristics between an overlapping portion overlapping two-dimensionally with the display area of the second display means, of a region overlapping two-dimensionally

with the display area of the first display means, and a portion of the region other than the overlapping portion.

[Claim 4] The display device according to any one of Claims 1 to 3, wherein the transflection means has a light-diffusing function.

[Claim 5] The display device according to any one of Claims 1 to 4, wherein the transflection means is a thin film comprising a reflective material and having a thickness allowing light to be substantially transmitted therethrough.

[Claim 6] The display device according to any one of Claims 1 to 4, wherein the transflection means is a thin film comprising a reflective material and having a plurality of fine apertures dispersed therein such that light is substantially transmitted therethrough.

[Claim 7] The display device according to any one of Claims 1 to 4, wherein the transflection means comprises a base member comprising a light transmissive material; and a light-diffusing layer having fine particles dispersed in the base member and comprising a light transmissive material having a different refractive index from that of the base member.

[Claim 8] The display device according to any one of Claims 1 to 4, wherein the transflection means comprises a base member comprising a light transmissive material; and a light-diffusing layer having fine particles dispersed in the

base member and comprising a reflective material.

[Claim 9] The display device according to any one of Claims 1 to 8, wherein the first light-emitting surface of the light-guiding member and the first display means have a light diffusion means interposed therebetween.

[Claim 10] An electronic apparatus comprising the display device according to any one of Claims 1 to 9; and control means for controlling the display device.

[Detailed Description of the Invention]

[0001]

[Technical Field of the Invention]

The present invention relates to a display device and an electronic apparatus, and in particular, it relates to the structure of a display device suitably mounted on a portable electronic apparatus.

[0002]

[Description of the Related Art]

In general, an electro-optical device such as a liquid crystal display device or an electro-luminescent display device is used as a display device mounted on a portable electronic apparatus. In particular, a portable phone has a compact liquid crystal display device mounted in a small casing thereof. In recent years, a portable phone of a double-sided display type, having compact liquid crystal display devices mounted on the front and back of a thin displaying portion thereof, is commercially available on the market. Such a portable phone has a pair of liquid crystal display devices accommodated in the displaying portion of the casing thereof so as to lie back on to each other and placed so as to be visible from both front and back sides thereof.

[0003]

Many liquid crystal display devices have a structure in

which a backlight serving as an illuminator is disposed behind a liquid crystal panel. Although a reflective liquid crystal display device having no such a backlight is available, its application is limited since its display is invisible at a dark place or at night. Although the liquid crystal display device equipped with a backlight has a drawback in thickness, with the recent advancements in higher definition and color display of a compact liquid crystal display device, most of portable electronic apparatuses have them mounted thereon. In recent years, there has been emerged a transflective liquid crystal display device equipped with a backlight and able to perform both transmissive display and reflective display.

[0004]

Since a portable electronic apparatus such as the above-mentioned portable phone has become more compact and thinner year by year, a thin liquid crystal display device is strongly required in accordance with this trend. In order to meet this requirement, a thinner liquid crystal panel and a thinner backlight are under development (for example, see Patent Document 1).

[0005]

[Patent Document 1]

Japanese Unexamined Patent Publication Application No. 2001-75903

[0006]

[Problems to be Solved by the Invention]

Unfortunately, the above-mentioned known portable phone of a double-sided display type has problems in that, since a pair of liquid crystal display devices must be accommodated in its casing so as to lie back on to each other, it is hard to make the casing thinner, and, even when each of the liquid crystal display devices is made thin, it is thicker and heavier than a normal portable phone of a single-sided display type.

[0007]

One method for solving the above problems lies in that a single backlight is shared by the front and back liquid crystal display devices so as to illuminate a pair of front and back liquid crystal panels. Whereas, in a portable phone of a double-sided display type, since the display areas of the front and back liquid crystal display devices are generally different from each other, when a single backlight is shared by them as mentioned above, the luminance distribution of a large main panel is affected by an illumination action of the backlight applied on a small sub-panel disposed behind the main panel, thereby causing a risk that a shadow of the sub-panel is reflected in a display image of the main panel and thus its display quality deteriorates.

[0008]

With this background, the present invention has been made in order to solve the above problems. Accordingly, it is an object of the present invention to provide a display device which offers double-sided display and achieves a thin structure and which prevents deterioration in display quality of both front and back display means when an illumination means such as a backlight is shared by these display means.

[0009]

[Means for Solving the Problems]

In order to achieve the above-mentioned object, a display device according to the present invention includes a first display means having a display surface on the front surface thereof; a second display means having a display surface on the rear surface thereof; and a common illumination means interposed between the first display means and the second display means, for illuminating both the first display means and the second display means with light. The illumination means includes a light-guiding member including a first light-emitting surface opposed to the first display means and a second light-emitting surface opposed to the second display means, and the second light-emitting surface of the light-guiding member and the second display means have a transflection means interposed

therebetween.

[0010]

According to the present invention, with the common illumination means constructed so as to illuminate both the first display means and the second display means with light, one of two illumination means can be eliminated, thereby achieving a thinner and lighter device by that much. Also, with the transflection means interposed between the second light-emitting surface of the light-guiding member of the illumination means and the second display means, since part of light emitted from the second light-emitting surface of the light-guiding member is transmitted through the transflection means and is then directed towards the second display means, while the second display means is constructed so as to be illuminated with light, the remaining light emitted from the second light-emitting surface of the light-guiding member can be reflected at the transflection means so as to be directed towards the first display means. Accordingly, it is possible to put a priority on the illumination state of the first display means, and hence the display quality of the first display means can be improved.

[0011]

Also, with the above structure, the first light-emitting surface and the first display means may also have a transflection means interposed therebetween. In this case,

the second display means also obtains an optical effect equivalent to that of the first display means.

[0012]

In the present invention, the display area of the first display means may preferably extend so as to overlap two-dimensionally with the display area of the second display means and an area lying outside the latter display area. With this structure, since the display area of the first display means extends so as to overlap two-dimensionally not only with the display area of the second display means but also with the area outside the latter display area, light emitted from the common illumination means towards the second display means causes the display feature of the first display means to be optically affected due to the fact that the display area of the second display means presents behind the first display means. Hence, a shadow of the display area of the second display unit is sometimes reflected in the display surface of the first display unit. However, in the display device according to the present invention, since the transflection means is interposed between the second light-emitting surface of the light-guiding member and the second display means as described above, the optical affect caused by the second display means can be reduced, and thus the display quality of the first display means can be improved.

[0013]

In the present invention, the transflection means may preferably have a light-diffusing function. With this structure, the light-diffusing function improves the evenness of illumination light of the illumination means, thereby further preventing the unevenness of display of the first display means and the second display means. In particular, when the display device has a structure in which light reflected at the transflection means is diffused, the evenness of light in the light-guiding member is improved, and the illuminance distribution on the first display means is made uniform, thereby further preventing the unevenness of display of the first display means.

[0014]

In the present invention, the transflection means may preferably have different optical characteristics between an overlapping portion overlapping two-dimensionally with the display area of the second display means, of a region overlapping two-dimensionally with the display area of the first display means, and a portion of the region other than the overlapping portion. With this structure, the transflection means has different optical characteristics between the overlapping portion and the remaining portion of the region from each other, thereby making optical actions of the transflection means applied on the display area of

the first display means different between the overlapping portion and the remaining portion different. Accordingly, an optical difference (a difference in luminance levels) between the overlapping portion and the remaining portion in the display area of the first display means can be reduced, or the display quality of the second display means can be improved.

[0015]

More particularly, in the case where the transflection means is disposed across the entire region, assuming that the second display means is disposed behind the overlapping portion of the region and another setting is disposed behind the portion other than the overlapping portion, when the transflection means is formed so as to have uniform optical characteristics across the entire region, a difference in reflectances between the second display means and the other setting causes a black shadow or a white shadow of the second display means to be reflected in the display area of the first display means. Accordingly, when the second display means and the other setting have a difference in reflectances therebetween like this, by making the optical characteristics of the transflection means different between the overlapping portion and the remaining portion as mentioned above, the foregoing back or white shadow can be less noticeable. Meanwhile, the optical characteristics of

the transflection means mean characteristics such as a light reflectance, a light transmittance, a light absorptance, and a light-diffusing rate, possibly affecting on the display features of the first display means and the second display means.

[0016]

In the present invention, the transflection means may preferably be a thin film composed of a reflective material and having a thickness allowing light to be substantially transmitted therethrough. With this structure, since the transflection means is provided with a light transmittivity by adjusting the thickness of a thin film composed of a reflective material, a step such as patterning can be eliminated, thereby easily making the transflection means. A thin metal film is named as the reflective material. In particular, aluminum, an aluminum alloy, silver, a silver alloy, and the like are preferable as the reflective material.

[0017]

In the present invention, the transflection means may preferably be a thin film composed of a reflective material and having a plurality of fine apertures dispersed therein such that light is substantially transmitted therethrough. With this structure, since the transflection means is provided with a light transmittivity by having the fine

apertures dispersed in a thin film composed of a reflective material, the light transmittance is accurately controlled by changing the aperture area ratio (the size and the density) of the apertures.

[0018]

In the present invention, the transflection means may be formed by a base member composed of a light transmissive material and a light-diffusing layer having fine particles dispersed in the base member and composed of a light transmissive material having a different refractive index from that of the base member. With this structure, the transmittivity and the reflectivity can be adjusted with a difference in refractive indexes between the base material and the fine particles and also with the size and the density of the fine particles, and also, the unevenness of display can be prevented by the light-diffusing action. In particular, with this structure, the transmittance can be easily made higher.

[0019]

In the present invention, the transflection means may be formed by a base member composed of a light transmissive material and a light-diffusing layer having fine particles dispersed in the base member and composed of a reflective material. With this structure, since light is diffused by the fine particles dispersed in the base member and composed

of a reflective material, the transmittivity and the reflectivity can be adjusted with the size and the density of the fine particles, and also, the unevenness of display can be prevented by the light-diffusing action. In particular, with this structure, the reflectance can be easily made higher.

[0020]

In the present invention, the first light-emitting surface of the light-guiding member and the first display means may preferably have a light diffusion means interposed therebetween. With this structure, since the light diffusion means is interposed between the first light-emitting surface and the first display means, the evenness of the illuminance distribution of the illumination means can be improved, thereby further preventing the unevenness of display of the first display means.

[0021]

Incidentally, the light diffusion means may be formed so as to have different optical characteristics between the overlapping portion overlapping two-dimensionally with the display area of the second display means, of the region overlapping two-dimensionally with the display area of the first display means, and the portion of the region other than the overlapping portion. With this structure, the unevenness of display of the first display means may be

further prevented.

[0022]

The light diffusion means may be formed by a base member composed of a light transmissive material and a light-diffusing layer having fine particles dispersed in the base member and composed of a light transmissive material having a different refractive index from that of the base member. Alternatively, the light diffusion means may be formed by a base member composed of a light transmissive material and a light-diffusing layer having fine particles dispersed in the base member and composed of a reflective material. Further alternatively, the light diffusion means may be formed by a light diffusing layer composed of a light transmissive material and having a structure in which fine undulations are formed on the surface thereof.

[0023]

Next, an electronic apparatus according to the present invention may preferably include any one of the above-mentioned display devices and control means for controlling the display device. Especially, as the above electronic apparatus, a portable electronic apparatus is effective from the viewpoint of easily achieving a thin casing thereof.

[0024]

[Description of the Embodiments]

Referring now to the accompanying drawings, preferred

embodiments of display devices and an electronic apparatus according to the present invention will be described in detail.

[0025]

[First Embodiment]

Referring first to Fig. 1, a liquid crystal display device 100 according to a first embodiment of the present invention will be described. The liquid crystal display device 100 includes a first display means 110, a second display means 120, and an illumination means 130.

[0026]

The first display means 110 is a liquid crystal panel and is formed such that substrates 111 and 112 composed of glass or plastic are bonded to each other via a sealant 113 and have liquid crystal 114 interposed therebetween. The liquid crystal 114 is formed so as to receive predetermined electrical fields with electrodes formed on the inner surfaces of the substrates 111 and 112. The substrate 112 has a polarizer 115 disposed on the outer surface thereof (that is, on the front surface side or on the observing side of the first display means), and the substrate 111 also has the polarizer 116 disposed on the outer surface thereof (that is, on the back surface side).

[0027]

The second display means 120 is also a liquid crystal

panel and is formed such that substrates 121 and 122 composed of glass or plastic are bonded to each other via a sealant 123 and have liquid crystal 124 interposed therebetween. The liquid crystal 124 is formed so as to receive predetermined electrical fields with electrodes formed on the inner surfaces of the substrates 121 and 122. The substrate 122 has a polarizer 125 disposed on the outer surface thereof (that is, on the back surface side or the observing side of the second display unit), and the substrate 121 has a polarizer 126 on the outer surface thereof (that is, on the front surface side).

[0028]

The first display means 110 and the second display means 120 have the illumination means 130 interposed therebetween. The illumination means 130 constitutes a backlight. The illumination means 130 includes a light source 131 formed by, for example, a cold cathode fluorescent tube or a light emitting diode (LED), and a light guiding plate 132 receiving light emitted from the light source 131. The light guiding plate 132 is composed of a transparent material such as an acrylic resin. In the illumination means 130, the light guiding plate 132 is a plate disposed so as to be orthogonal to an optical-axis direction of the display device, and the light source 131 is disposed along a side surface of the light guiding plate 132.

The light guiding plate 132 is disposed such that a light incident surface 132a serving as a side surface thereof is opposed to the light source 131, a first light-emitting surface 132b serving as a front surface thereof (an upper surface thereof in the figure), faces the first display means 110, and a second light-emitting surface 132c serving as a back surface thereof (a lower surface thereof in the figure) faces the second display means 120.

[0029]

The light guiding plate 132 is formed so as to output illumination light from the first light-emitting surface 132b toward the first display means 110 and also to output illumination light from the second light-emitting surface 132c toward the second display means 120 while allowing light received from the light source 131 to propagate therein. In the light guiding plate 132, light incident on the first light-emitting surface 132b and the second light-emitting surface 132c at an angle smaller than a critical angle is subjected to total reflection, and light incident on the same at the critical angle or greater is outputted outside from the first light-emitting surface 132b and the second light-emitting surface 132c. Especially, although not shown in the figure, either or both the first light-emitting surface 132b and the second light-emitting surface 132c may have undulated surfaces or scattering layers formed

thereon serving as optical deflectors for outputting the light introduced from the light source 131 along or close to the optical axis directions of the first display means 110 and the second display means 120.

[0030]

The second light-emitting surface 132c of the light guiding plate 132 and the second display means 120 have a transflection means 141 interposed therebetween. The transflection means 141 suffices to have a structure in which part of illumination light from the illumination means is reflected thereat towards the front surface side and at least part of the remaining of the illumination light is transmitted therethrough towards the back surface side. Also, the transflection means is made from, for example, a thin metal film or a metal film having a large number of fine apertures dispersed therein. In addition, the transflection means 141 may be disposed while being bonded to the rear surface of the light guiding plate 132 or may be formed from a sheet or a plate independent of the light guiding plate 132. Incidentally, although the transflection means according to the present invention suffices to be interposed between the second light-emitting surface 132c of the illumination means 130 and the second display means 120 and has no limitations other than this, the following description is based on the assumption that the

transflection means 141 according to the present embodiment is basically formed so as to entirely cover the second light-emitting surface 132c of the light guiding plate 132 and to have two-dimensionally-uniform optical characteristics.

[0031]

Fig. 2 illustrates example structures of the foregoing transflection means 141. In the transflection means having the example structure shown in Fig. 2(a), a reflective thin film 141B composed of a reflective material, for example, metal such as aluminum is formed on the front surface of a transparent substrate 141A composed of glass, a plastic film, or the like. White pigment such as white resin and titanium oxide, metals such as aluminum and silver, and so forth are named as the reflective material. Here, the light guiding plate 132 may be used instead of the foregoing transparent substrate 141A and the reflective thin film 141B may be formed on the second light-emitting surface 132c. This applies likewise to the other structures shown in Figs. 2(b) to 2(e).

[0032]

By making a thin film from metal such as aluminum or silver so as to have a thickness of about 10 to 50 nm, the reflective thin film 141B has an average transmittance of about 30% to 70% in a visible light range as its optical

characteristic. The above thin film is formed by deposition, spattering, laser abrasion, or the like. The reflectance and the transmittance in this example structure can be adjusted by the film thickness.

[0033]

Also, the transflection means may be made from a known dielectric multilayer film instead of the reflective material as mentioned above.

[0034]

In the example structure shown in Fig. 2(b), a reflective thin film 141C composed of a reflective material, for example, metal such as aluminum is formed on the front surface of the transparent substrate 141A. White pigment such as white resin and titanium oxide, metal such as aluminum and silver, and so forth are named as the reflective material. The reflective thin film 141C is formed so as to have an average reflectance of about 90% or more as a whole in the visible light range and also to have a large number of fine apertures 141Ca formed therein. The fine apertures 141Ca are dispersed over the entire surface of the reflective thin film 141C. An equivalent aperture diameter of each fine aperture 141Ca (an aperture diameter of a round aperture having the same area as that of the fine aperture) is preferably about 1 to 100 μm, and is more preferably about 5 to 30 μm. Especially, the fine apertures

are preferably formed so as to be smaller than the sizes of pixels of the first and second display means and also to be spaced at intervals smaller than the pitches of the pixels. The reflectance and the transmittance of this example structure can be adjusted by the aperture area ratio of the fine apertures 141Ca. The aperture area ratio is determined by the equivalent aperture diameter and the formed density of the fine apertures 141Ca.

[0035]

In the example structure shown in Fig. 2(c), a light-diffusing layer 141D basically composed of a light transmissive material is formed on the front surface of the transparent substrate 141A. The light-diffusing layer 141D includes a transparent substrate 141d1 composed of acrylic resin or the like and fine particles 141d2 dispersed in the substrate 141d1. The substrate 141d1 and the fine particles 141d2 are composed of materials having different refractive indexes from each other. Particles composed of silica, acrylic resin, and the like are named as the fine particles. The diameters of the particles are preferably about 1 to 10 μm, and more preferably about 4 to 5 μm.

[0036]

In this example structure, since the particles having different refractive indexes from each other are dispersed in the substrate, light is scattered or dispersed in a

macroscopic view, whereby optical characteristics can be obtained with which part of the light is reflected thereat and the remaining light is transmitted therethrough. The reflectance and the transmittance of this example structure can be adjusted by a difference in refractive indexes between the substrate and the particles, the size and the distribution density of the particles, and the like.

[0037]

In the example structure shown in Fig. 2(d), a light-diffusing layer 141E basically composed of a light transmissive material is formed on the front surface of the transparent substrate 141A. The light-diffusing layer 141E includes a transparent substrate 141e1 composed of acrylic resin or the like and light reflective fine particles 141e2 dispersed in the substrate 141e1. The fine particles 141e2 are composed of a reflective material. White pigment such as white resin and titanium oxide, metal such as aluminum and silver, and so forth are named as the reflective material. The diameters of the particles 141e1 are preferably about 1 to 10 μm, and more preferably about 2 to 3 μm.

[0038]

In this example structure, since the particles composed of a reflective material are dispersed in the substrate, light is scattered or dispersed in a macroscopic view,

whereby optical characteristics can be obtained with which part of the light is reflected thereat and the remaining light is transmitted therethrough. The reflectance and the transmittance of this example structure can be adjusted by the reflectance, the size, and the density of the particles, and the like.

[0039]

In the example structure shown in Fig. 2(e), the reflective thin film 141B, the same as that shown in Fig. 2(a) composed of a reflective material, is formed on the front surface of the transparent substrate 141A, and a diffusing layer 141F composed of a light transmissive material (preferably of a transparent material) and having fine undulations on the surface thereof is additionally formed on the thin film 141B. The surface undulation of the dispersing layer 141F has a depth of about 2 to 3 μm formed at an interval of, for example, about 1 to 10 μm, preferably about 3 to 4 μm. This surface undulation is formed by patterning such as photolithography. For example, the above-mentioned surface undulation is formed such that after applied on the reflective thin film 141B, a transparent photosensitive resin is exposed with a mask pattern having openings formed with an interval corresponding to the above-mentioned surface undulation and is then developed. Here, a step of additionally applying an additional transparent

resin on the foregoing developed transparent resin or heating the developed transparent resin so as to be softened may be added so as to provide a smooth surface undulation.

[0040]

According to this example structure, the transflection means obtains reflection and transmission characteristics in accordance with the thickness of the reflective thin film 141B in the same fashion as mentioned above, and also is provided with a light-diffusing function since light incident on and reflected at the reflective thin film 141B is scattered by the diffusing layer 141F, thereby improving the evenness of the luminance distributions of the first display means 110 and the second display means 120.

[0041]

Also, the light guiding plate 132 and the first display means 110 have a light diffusion means 142 interposed therebetween. The light diffusion means 142 is intended to prevent the unevenness of display (the uneven brightness across the display surface) caused by the structures of the light guiding plate 132 and the other components lying on the back surface side thereof (lying on the lower side in the figure) by appropriately diffusing light emitted from the light guiding plate 132. The light diffusion means 142 may have an example structure, for example, in which fine particles composed of an acrylic resin or the like (and

having an example diameter of about 2 to 3 μm) are dispersed in a base material composed of an acrylic resin or the like having a different refractive index from that of the fine particles, or in which fine undulations are provided on the surface thereof. More particularly, the same structure as those shown in Fig. 2(c) or 2(d), or a structure formed by removing the reflective thin film 141B from the structure shown in Fig. 2(e) can be used. This light diffusion means 142 may be disposed while being bonded to the front surface of the light guiding plate 132 or may be formed from a sheet or a plate independent of the light guiding plate 132.

[0042]

Also, the light guiding plate 132 and the second display means 120, (the transflection means 141 and the second display means 120 in the case of this embodiment) have a light diffusion means 145 interposed therebetween. The light diffusion means 145 has the same structure as that of the light diffusion means 142.

[0043]

Incidentally, in the present embodiment, since an overlapping portion, lying in a region overlapping two-dimensionally with the display area of the first display means 110 and overlapping two-dimensionally with the display area of the second display means 120, and the remaining portion lying in the region have different optical

structures from each other, in order to improve the evenness of the display surface of the first display means, the foregoing light diffusion means may be formed such that the overlapping portion and the remaining portion have different diffusion rates (for example, haze values) from each other.

[0044]

In this embodiment, in order to increase the percentage of light substantially contributing to display in each of the first display means 110 and the second display means 120, the illumination means 130 and the first display means 110 have light collection means 143 and 144 (prism sheets 143 and 144) interposed therebetween, and the illumination means 130 and the second display means 120 have light collection means 146 and 147 (prism sheets 146 and 147) interposed therebetween. Each light collection means has a prism surface for refracting light so as to direct the light along or close to an optical-axis direction of the display device (the vertical direction in the figure). More particularly, the prism surface is formed by a plurality of ribs, each having a triangular cross section, juxtaposed with each other in a stripe pattern on the surface of the corresponding collection means. The light collection means 143 and 144 as well as the light collection means 146 and 147 are disposed such that the foregoing corresponding ribs extend along directions substantially perpendicular to each

other.

[0045]

Next, an operation and an effect of this embodiment having the above-described structure will be described. In the following description, for simplicity of description, it is assumed that both the first display means 110 and the second display means 120 serving as liquid crystal panels are formed so as to perform display in a TN-type liquid crystal mode, that the polarizer 115 transmits linearly polarized light A having a plane of vibration parallel to the plane of the figure (first polarized light), and reflects linearly polarized light B having a plane of vibration orthogonal to the plane of the figure (second polarized light), and that the polarizer 116 transmits the linearly polarized light B (third polarized light), and absorbs the linearly polarized light A (fourth polarized light). In addition, it is assumed that the polarizer 125 transmits the linearly polarized light A and absorbs the linearly polarized light B, and that the polarizer 126 transmits the linearly polarized light B and absorbs the linearly polarized light A. That is, although directional relationships among the planes of vibration of the first polarized light to the fourth polarized light are generally arbitrary, in the following description, the first polarized light and the fourth polarized light exhibit the same

polarized state as each other, and the second polarized light and the third polarized light exhibit the same polarized state as each other.

[0046]

Light emitted from the light source 131 is introduced in the light guiding plate 132 and is emitted little by little therefrom towards the front and back surface sides while propagating in the light guiding plate 132. First, illumination light emitted towards the first display means 110 passes through the light diffusion means 142, becomes the linearly polarized light B upon passing through the polarizer 116, passes through the light collection means 143 and 144, and is then incident on the liquid crystal 114. Here, when the liquid crystal 114 is in an OFF-state, upon passing through the liquid crystal 114, the illumination light becomes the linearly polarized light A due to the optical rotary power of the liquid crystal, passes through the polarizer 115, and is emitted towards the front surface side as transmissive light T1. When the liquid crystal 114 is in an ON-state, since the illumination light remains as the linearly polarized light B even when passing through the liquid crystal 114, it is absorbed by the polarizer 115.

[0047]

In the meantime, external light incident on the first display means 110 becomes the linearly polarized light A

upon passing through the polarizer 115 and is incident on the liquid crystal 114. Here, when the liquid crystal 114 is in an OFF-state, the external light becomes the linearly polarized light B, is transmitted through the polarizer 116, and enters the light guiding plate 132 and then, part of this light is reflected at the transflection means 141, becomes the linearly polarized light A upon passing again through the polarizer 116 and the liquid crystal 114, is transmitted through the polarizer 115, and is emitted as reflective light RD1. Also, when the liquid crystal 114 is in an ON-state, since the linearly polarized light A of the external light passing through the polarizer 115 remains as the linearly polarized light A even when passing through the liquid crystal 114, it is absorbed by the polarizer 116.

[0048]

Incidentally, when the foregoing light collection means 143 and 144 are disposed, since external light is scattered upon being incident on these light collection means, the reflective light RD1 is not substantially obtained. Accordingly, when it is expected to effectively use the foregoing reflective light RD1, it is preferable that none of these light collection means be disposed.

[0049]

Next, part of illumination light emitted from the illumination means 130 towards the second display means 120

is transmitted through the transflection means 141, passes through the light diffusion means 145, becomes the linearly polarized light B upon passing through the polarizer 126, and passes through the liquid crystal 124. When the liquid crystal 124 is in an OFF-state, upon passing through the liquid crystal 124, the linearly polarized light B becomes the linearly polarized light A, is transmitted through the polarizer 125, and is emitted as transmissive light T2 towards the back surface side. When the liquid crystal 124 is in an ON-state, since the linearly polarized light B remains as it is even when passing through the liquid crystal 124, it is absorbed the polarizer 125.

[0050]

In the meantime, of external light incident on the second display means 120, the linearly polarized light A is transmitted through the polarizer 125 and is incident on the liquid crystal 124. When the liquid crystal 124 is in an OFF-state, the linearly polarized light A becomes the linearly polarized light B and passes through the polarizer 126 and the light diffusion means 143, and then, part of this light is reflected at the transflection means 141 while other part of the light is introduced in the light guiding plate 132. The linearly polarized light B reflected at the transflection means 141 passes through the light diffusion means 143 and the polarizer 126 as it is, becomes the

linearly polarized light A upon passing again through the liquid crystal 124, is transmitted through the polarizer 125, and is emitted as reflective light RD2. When the liquid crystal 124 is in an ON-state, since the above-mentioned linearly polarized light A remains as it is even when passing through the liquid crystal 124, it is absorbed by the polarizer 126.

[0051]

Incidentally, when the foregoing light collection means 146 and 147 are disposed, since external light is scattered upon being incident on these light collection means, the reflective light RD2 is not substantially obtained. Accordingly, when it is expected to effectively use the foregoing reflective light RD2, it is preferable that none of these light collection means be disposed.

[0052]

As described above, in this embodiment, the first display means 110 performs display with the transmissive light T1 and the reflective light RD1. Also, the second display means 120 performs display with the transmissive light T2 and the reflective light RD2. The presence of the reflective light RD1 and the reflective light RD2 prevents deterioration in visibility of display in the case of observing an object at a bright place like out of doors or in the case of cutting an amount of illumination light of

the illumination means 130.

[0053]

In this embodiment, the illumination means 130 is formed so as to emit light towards both the first display means 110 and the second display means 120, and in particular, the light guiding plate 132 interposed between the first display means 110 and the second display means 120 is shared by them, thereby making the overall structure of the display device 100 thin and light. Also, with the transflection means 141 disposed as mentioned above, light in the light guiding plate 132 can be divided towards both the first display means 110 and the second display means 120 respectively disposed on the front and back sides, the evenness of illumination light emitted from the light guiding plate 132 towards each of the front and back sides can be improved, and also, external light incident on the first display means 110 and the second display means 120 can be reflected at the transflection means so as to serve as part of display light.

[0054]

In particular, with the presence of the transflection means 141, the illuminance distribution of the illumination means 130 on the first display means 110 is unlikely optically affected by the presence of the second display means 120. With this structure, even when the display area

of the first display means 110 is set greater than that of the second display means 120 as shown in the figure, a shadow of the display area of the second display means 120 is unlikely reflected in the display surface of the first display means 110, thereby improving the display quality of the first display means 110.

[0055]

Incidentally, as mentioned above, although the display areas of the first and second display means 110 and 120 overlap with each other, in the case where the one includes the other or in the case where the two display areas do not partially overlap with each other, the unevenness of display becomes generally noticeable. Hence, the above-described structure is especially effective in these cases. However, regardless of the above-mentioned cases, when a common illumination means is used to illuminate the display means lying on both the front and back sides, the unevenness of the illuminance distribution of the illumination means is in general likely to occur. Hence, different from the above cases, even when both the display areas have almost the same size as each other and overlap so as to agree two-dimensionally with each other, the structure of the display device according to the present invention is technically effective in order to achieve the evenness of the luminance of each of the display means.

[0056]

[Second Embodiment]

Referring next to Fig. 3, a display device according to a second embodiment of the present invention will be described. Since the display device according to the second embodiment basically has the same structure as that of the display device according to the first embodiment shown in Fig. 1 except for its transflection means, illustrations and descriptions thereof will be omitted.

[0057]

As shown in Fig. 3(a), a transflection means 241 according to this embodiment is interposed between the second light-emitting surface 132c of the light guiding plate 132 and the second display means 120 so as to entirely cover a region AR1 overlapping two-dimensionally with the display area of the first display means 110. The transflection means 241 has an overlapping portion AR2 which overlaps two-dimensionally with the display area of the second display means 120 and which serves as an aperture 241A, and in the region AR1, a portion AR3 other than the overlapping portion AR2 serves as a reflector 241R reflecting visible light thereat.

[0058]

With this structure, the second display means 120 is illuminated with light emitted from the light guiding plate

132 and passing through the aperture 241A, thereby easily achieving bright display of the second display means 120. Also, with respect to the first display means 110, since substantially all part of light is reflected at the portion AR3, an amount of light contributing to display as a whole can be increased. However, in this case, since the intensity of the illumination light with which the first display means 110 is illuminated decreases in the overlapping portion AR2, it is preferable that the display device preferably have a structure in which the intensity distribution of the illumination light can be modified by adjusting a light-diffusing action of the light diffusion means 142, a light-emitting distribution of the light guiding plate 132, and the like.

[0059]

Fig. 3(b) illustrates a modification of this embodiment. A transflection means 241' according to the modification is formed such that a large number of fine apertures 241A' are dispersed in the reflective surface of the overlapping portion AR2 and that a portion other than the overlapping portion AR2 has no apertures and serves as the reflector 241R reflecting light thereat. In this modification, the second display means 120 is illuminated with light passing through the fine apertures 241A' formed in the overlapping portion AR2. However, in the overlapping portion AR2, since

light is reflected at the reflective surface other than the fine apertures 241A' towards the first display unit 110, a difference in brightnesses of display between two parts of the display surface of the first display means 110 respectively corresponding to the overlapping portion AR2 and the remaining portion AR3 can be reduced. Incidentally, also in this case, in order to further prevent the unevenness of display of the first display means 110, it is preferable that the display device have a structure in which the intensity distribution of the illumination light can be modified by adjusting a light-diffusing action of the light diffusion means 142, a light-emitting distribution of the light guiding plate 132, and the like.

[0060]

[Third Embodiment]

Referring next to Fig. 4, a display device according to a third embodiment of the present invention will be described. Since the display device according to this embodiment basically has the same structure as that of the display device according to the first embodiment shown in Fig. 1 except for its transflection means, illustrations and descriptions thereof will be omitted.

[0061]

As shown in Fig. 4(a), in the region AR1, a transflection means 341 is formed such that the overlapping

portion AR2 is composed of a transflective material 341A having a predetermined reflectance (for example, in the range from 30 to 70%) and transmittance (for example, in the range from 30 to 70%), and the portion AR3 other than the overlapping portion AR2 is composed of a reflective material 341B having a lower transmittance than that of the overlapping portion AR2 while having substantially the same reflectance as that of the overlapping portion AR2 (for example, in the range from 30 to 70%). It is preferable that the transmittance of the reflective material 341B of the portion AR3 be nearly 0%. Such a material is easily formed, especially from a dielectric multilayer film.

[0062]

With this structure, the overlapping portion AR2 in the region AR1 allows illumination light emitted from the illumination means 130 to be reflected thereat towards the first display means 110 and to be transmitted therethrough towards the second display means 120 at the same time, whereby both display means can be illuminated at the same time. In addition, the portion AR3 other than the overlapping portion AR2 does not allow unnecessary light to be transmitted therethrough towards the back thereof because of its low transmittance, and also, since the reflectance of the portion AR3 is substantially the same as that of the overlapping region AR2, the unevenness of display of the

first display light 110 can be prevented.

[0063]

According to this example structure, when it is intended to iron out the unevenness of display of the first display means 110, a light loss of illumination light due to absorption by the portion AR3 is generated, whereby a light utilization efficiency of the display device as a whole decreases. In order to improve the light utilization efficiency, it is necessary to reduce the light loss in the portion AR3 by making the reflectance of the portion AR3 higher relative to that of the overlapping portion AR2, and it is preferable that the unevenness of display of the first display means 110 possibly caused by this arrangement be modified by the structures of the light-guiding plate 232, the light diffusion means 142, and so forth.

[0064]

Fig. 4(b) illustrates a modification of this embodiment. An entire transflection means 341' is composed of a reflective material. The transflection means 341' has a large number of fine apertures 341A' dispersed in the overlapping portion AR2, and, in place of the fine apertures 341A', also has fine absorbers 341B' composed of a black resin or the like and dispersed in the portion AR3 other than the overlapping portion AR2.

[0065]

The transflection means 341' has a structure in which the fine apertures 341A' in the overlapping portion AR2 allow the second display means 120 lying at the back thereof to be illuminated with light, and also the fine absorbers 341B' formed in the remaining portion AR3 reduce a difference in reflectances between the overlapping portion AR2 and the portion AR3. With this structure, the unevenness of display of the first display means 110 can be prevented.

[0066]

[Fourth Embodiment]

Referring next to Fig. 5, a display device according to a fourth embodiment of the present invention will be described. The display device according to this embodiment has a structure in which any one of the display devices according to the foregoing embodiments is accommodated in a casing composed of a synthetic resin, or the like. Accordingly, since the display device of this embodiment basically has the same structure as that of the display device according to the first embodiment shown in Fig. 1 except for its structural feature of accommodation with the casing, illustrations of the same parts in the present embodiment will be simplified and descriptions of the same parts will be omitted.

[0067]

As shown in Fig. 5(a), a display device 100' includes the first display means 110, the second display means 120, the illumination means 130, and the other foregoing components (not shown), which are the same as those of each of the display devices according to the foregoing embodiments, and these components are accommodated in a casing 150. The casing 150 is composed of, for example, a white synthetic resin. Making the casing 150 from a white material is preferable from the viewpoint of improving a utilization efficiency of illumination light of the illumination means 130 since this casing reflects light leaked from the light guiding plate 132 thereat and returns again to the light guiding plate 132.

[0068]

In this embodiment, an area not having the second display means 120 disposed therein, on the front surface of the second light-emitting surface of the light guiding plate 132 of the illumination unit 130 (the foregoing portion AR3), has an optical sheet 151 having predetermined optical characteristics and disposed therein. When viewed from the first display means 110, the optical sheet 151 is composed of a material having substantially the same reflectance as that of the second display means 120. With this structure, even when the transflection means 141 has entirely uniform optical characteristics, the unevenness of display of the

display surface of the first display means can be prevented.

[0069]

Fig. 5(b) illustrates a modification of the above embodiment. In a display device 100" of this modification, the first display means 110, the second display means 120, the illumination means 130, and the other components (not shown), which are the same as those of each of the display devices according to the foregoing embodiments, are accommodated in a casing 160. When viewed from the first display means 110, the casing 160 is composed of a material exhibiting substantially the same reflectance as that of the second display means 120. With this structure, even when the foregoing transflection means 141 has entirely uniform optical characteristics, the unevenness of display of the display surface of the first display means can be prevented.

[0070]

Incidentally, the optical sheet 151 and the casing 160 suffice to be formed such that, when observed from the first display means 110 via the illumination means 130, the illuminance distributions of a portion where the display area of the second display means 120 presents and another portion where the optical sheet 151 and the casing 160 are disposed are mutually made uniform regardless of the structures of the transflection means 141 and the light guiding plate 132.

[0071]

[Fifth Embodiment]

Referring next to Figs. 6 and 7, an electronic apparatus, including the display device 100 according to the first embodiment, according to a fifth embodiment of the present invention will be described. As shown in Fig. 6, the electronic apparatus according to this embodiment includes a control means 1100 for controlling the first display means (the liquid crystal display panel) 110, and a control means 1200 for controlling the second display means (the liquid crystal display panel) 120. The control means 1100 and 1200 are controlled by a central controller 1000 disposed in the electronic apparatus and formed by a microcomputer and so forth.

[0072]

The first and second display means 110 and 120 are respectively connected to drive circuits 110D and 120D including semiconductor ICs and the like, which are mounted on the corresponding panels or connected to the corresponding panels via respective wiring members, and these drive circuits 110D and 120D are respectively connected to the controllers 1100 and 1200. The control means 1100 and 1200 respectively include display-information output sources 1110 and 1210, display process circuits 1120 and 1220, power supply circuits 1130 and 1230, and timing

generators 1140 and 1240.

[0073]

Each of the display-information output sources 1110 and 1210 includes a memory such as a ROM (Read Only Memory) and/or a RAM (Random Access Memory), a storage unit such as a magnetic storage disk and/or an optical storage disk, and a tuning circuit for outputting a tuned digital image signal. Also, in response to a variety of clock signals generated by the timing generators 1140 and 1240, the display-information output sources 1110 and 1210 supply display information, in the form of an image signal according to a predetermined format or the like, to the display-information process circuits 1120 and 1220, respectively.

[0074]

Each of the display-information process circuits 1120 and 1220 includes a variety of known circuits such as a serial-parallel conversion circuit, an amplification and reversion circuit, a rotation circuit, a gamma correction circuit, and a clamp circuit, processes the input display information, and supplies the processed image information together with a clock signal CLK to the corresponding drive circuit. Each of the drive circuits 110D and 120D includes a scanning line drive circuit, a data line drive circuit, and a testing circuit. Also, each of the power supply circuits 1130 and 1230 feeds a predetermined voltage to each

of the above described corresponding components.

[0075]

The central controller 1000 sends original data for illumination/extinguishment commands and display information, and the like, if needed, to the display-information output sources 1110 and 1210 of the corresponding controllers 1100 and 1200, controls the display-information output sources 1110 and 1210 so as to output display information in response to the original data and the like, and also controls the first display means 110 and the second display means 120 so as to display required display images via the control means 1100 and 1200 and the drive circuits 110D and 120D, respectively. Also, the central controller 1000 is formed so as to control the illumination, extinguishment, and the like of the light source 131.

[0076]

Fig. 7 illustrates a portable phone 2000 serving as an embodiment of the electronic apparatus according to the present invention. The portable phone 2000 includes a main body 2001 having a variety of buttons disposed thereon and a microphone housed therein, and a display unit 2002 having a display screen and an antenna mounted thereon and a speaker housed therein, and the main body 2001 and the display unit 2002 are constructed so as to be mutually foldable. The display unit 2002 has the display device 100 housed therein,

while having the display screen of the first display means 110 disposed on the inner surface thereof so as to be visible and also the display screen of the second display means 120 disposed on the outer surface thereof so as to be visible.

[0077]

In this embodiment, as shown in Fig. 7(a), when the display unit 2002 is opened by separating from the main body 2001, in response to a command from the central controller 1000, the first display means 110 is illuminated, and a predetermined image is displayed. Also, as shown in Fig. 7(b), when the display unit 2002 is folded onto the main body 2001, the first display means 110 is extinguished, the second display means 120 is illuminated instead of the above extinguishment, and a predetermined image is displayed.

[0078]

In this embodiment, the display device 100 having a thin structure as mentioned above allows the display unit 2002 to have a thin structure, to have a simple internal structure, and to be easily assembled. Here, the electronic apparatus of this embodiment may also have the display devices in the second to fourth embodiments mounted thereon.

[0079]

Incidentally, the electro-optical device and the electronic apparatus according to the present invention are

not limited to the foregoing example illustrations, and it is needless to mention that a variety of modifications can be added without departing from the spirit of the present invention. For example, although a liquid crystal display panel is used as an electro-optical panel in each of the foregoing embodiments, any one of a variety of electro-optical panels such as an organic electro-luminescence panel, a plasma display panel, and a field-emission display panel can also be used as the electro-optical panel according to the present invention. Also, although the liquid crystal display panel of a passive matrix type is basically illustrated in the foregoing embodiments, the present invention is likewise applicable to that of an active matrix type.

[Brief Description of the Drawings]

[Fig. 1] Fig. 1 a sectional view schematically illustrating the configuration of a first embodiment according to the present invention.

[Fig. 2] Fig. 2 includes sectional views schematically illustrating the structures (a) to (e) of a transflection means of the first embodiment.

[Fig. 3] Figs. 3(a) and 3(b) are plan views schematically illustrating the structures of a transflection means according to a second embodiment of the present invention.

[Fig. 4] Figs. 4(a) and 4(b) are plan views schematically

illustrating the structures of a transflection means according to a third embodiment of the present invention.

[Fig. 5] Figs. 5(a) and 5(b) are sectional views schematically illustrating the configuration of a fourth embodiment according to the present invention.

[Fig. 6] Fig. 6 is a structural block diagram illustrating the example structure of an electronic apparatus.

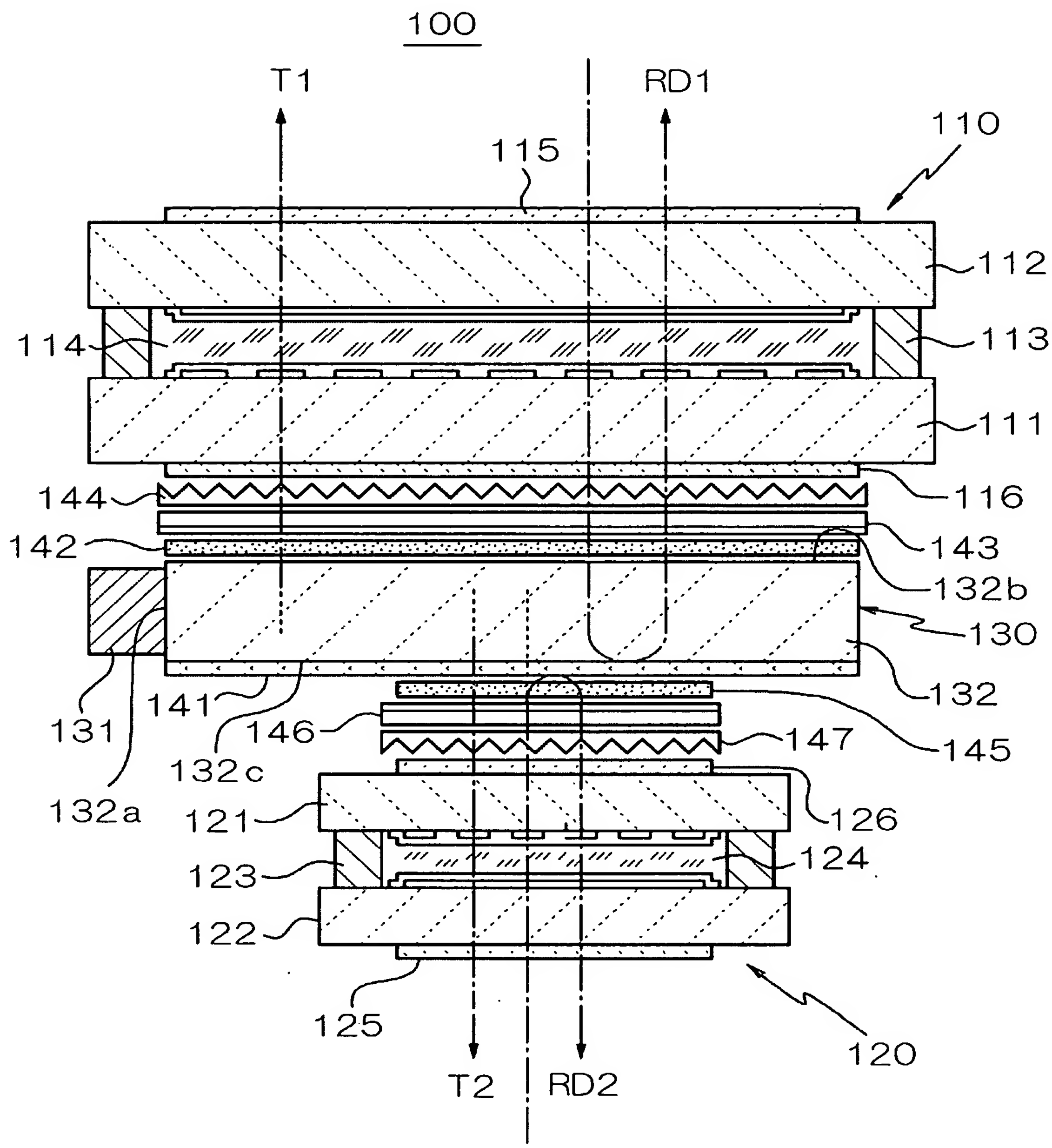
[Fig. 7] Figs. 7(a) and 7(b) are schematic perspective views of a portable phone illustrating the example structure of the electronic apparatus.

[Reference Numerals]

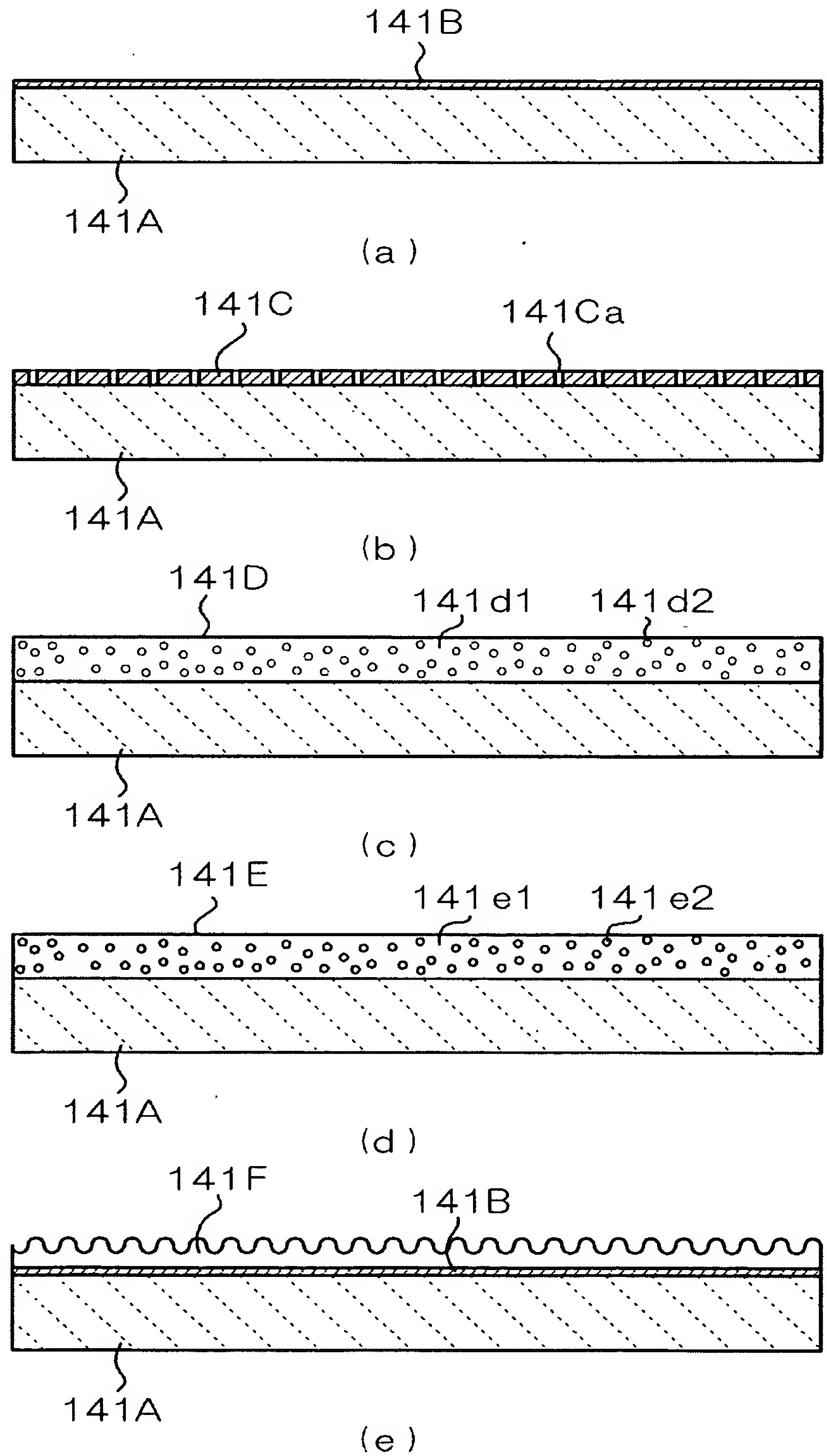
100 ... display device; 110 ... first display means; 120 ... second display means; 130 ... illumination means; 115, 116, 125, 126 ... polarizers; 131 ... light source; 132 ... light guiding plate; 141 ... transflection means; 142, 145 ... light diffusion means; 143, 144, 146, 147 ... light collection means

[Name of Document] DRAWINGS

[FIG. 1]

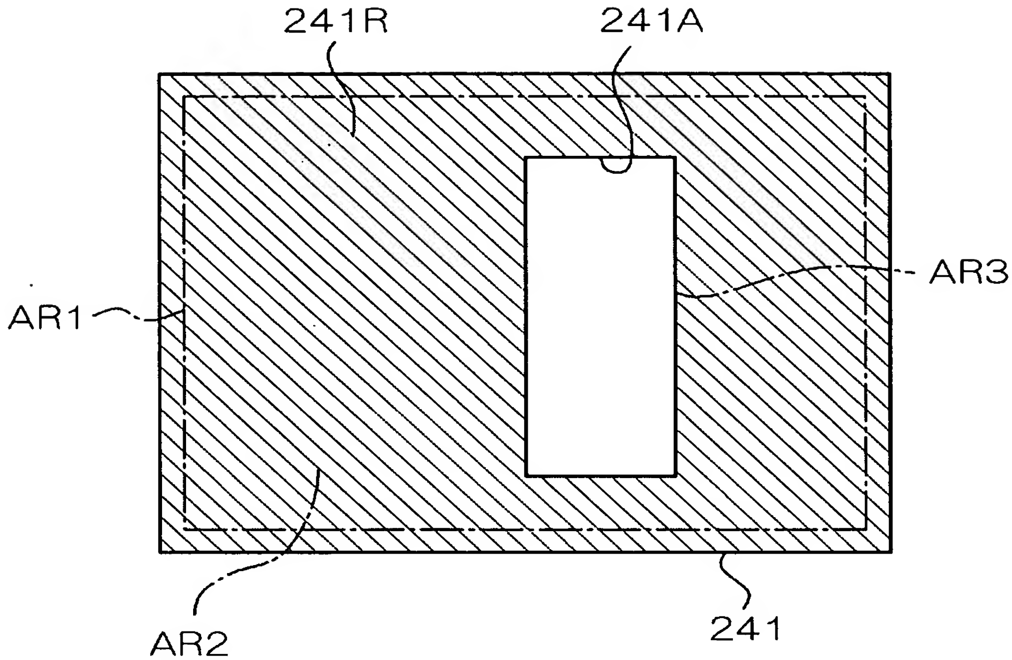


[FIG. 2]

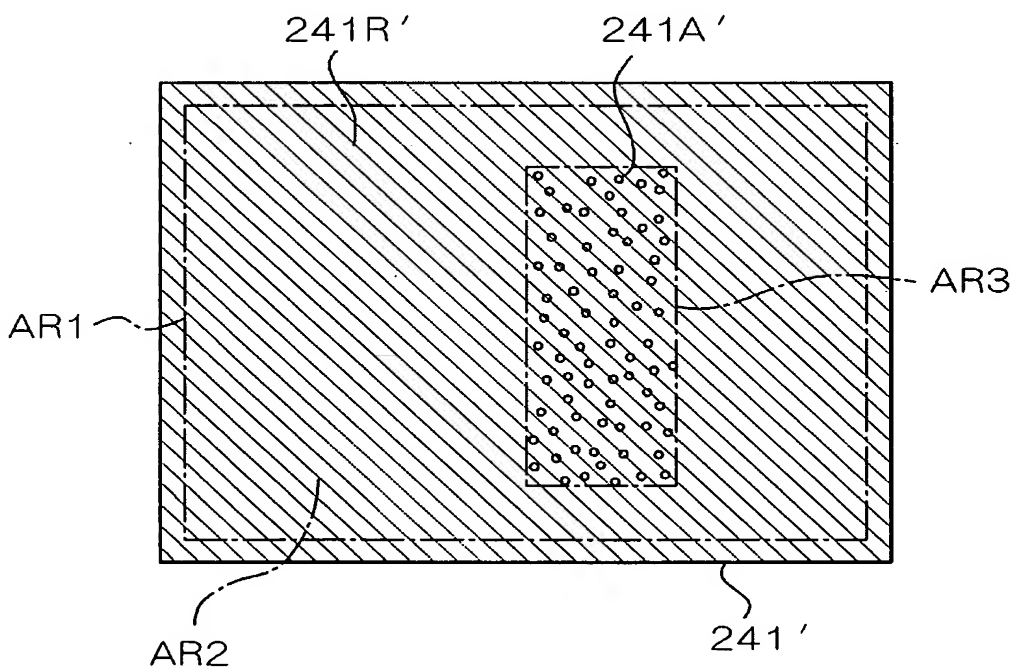


141B
141A
(a)
141C
141Ca
141A
(b)
141D
141d1
141d2
141A
(c)
141E
141e1
141e2
141A
(d)
141F
141B
141A
(e)

[FIG. 3]

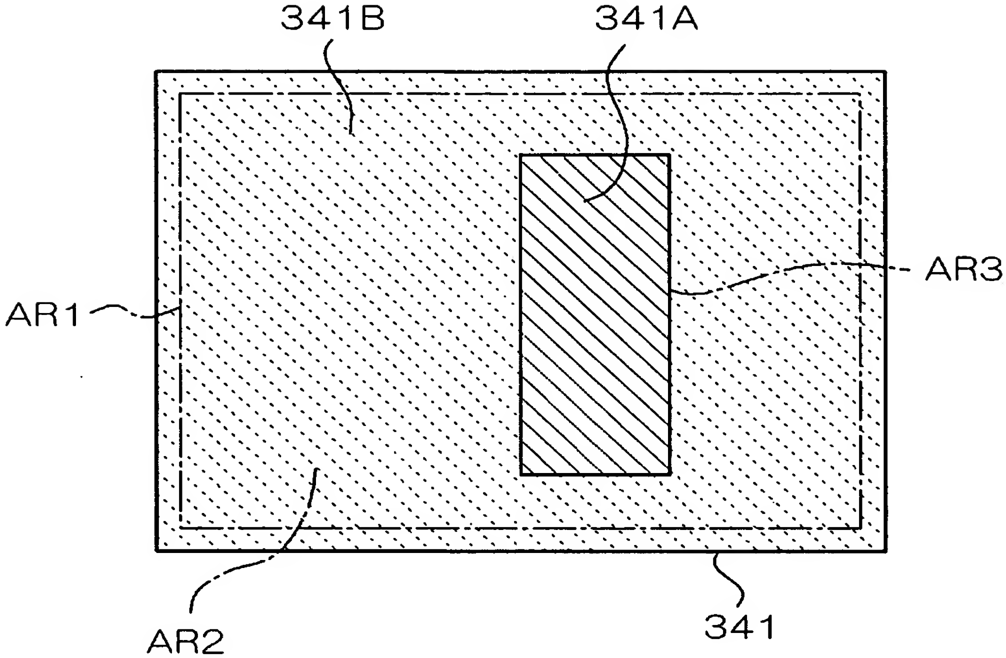


(a)

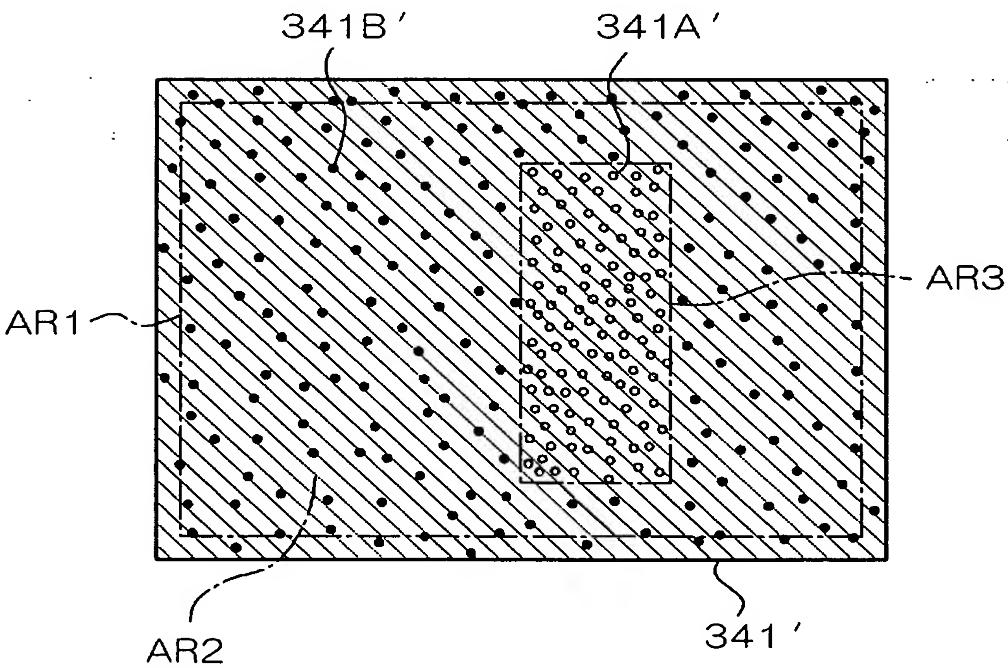


(b)

[FIG. 4]

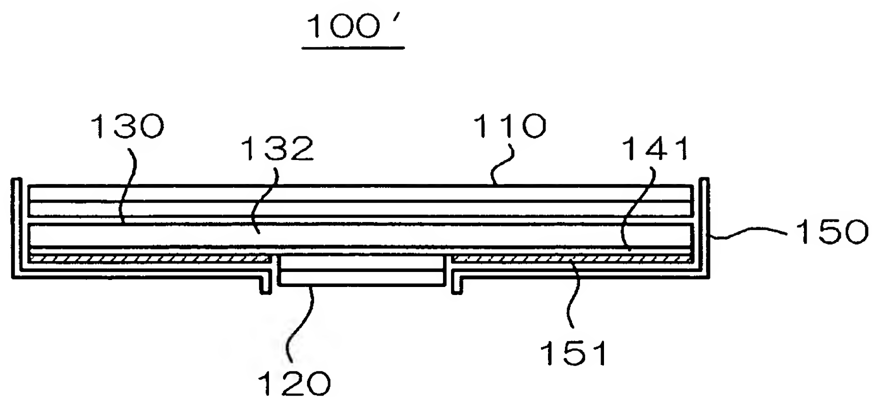


(a)

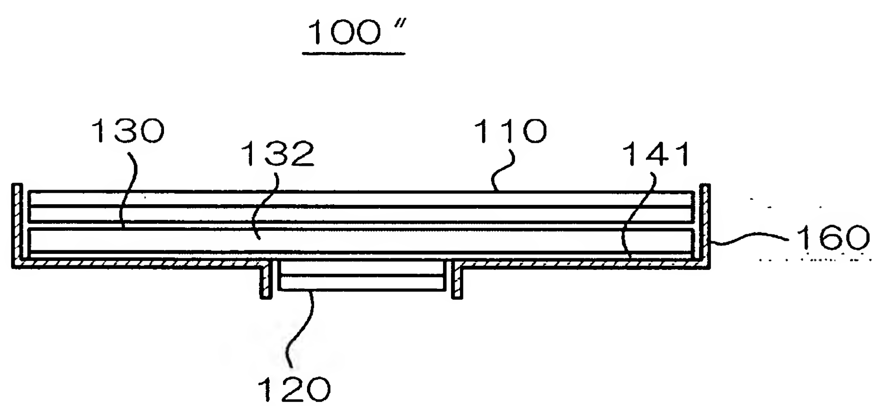


(b)

[FIG. 5]

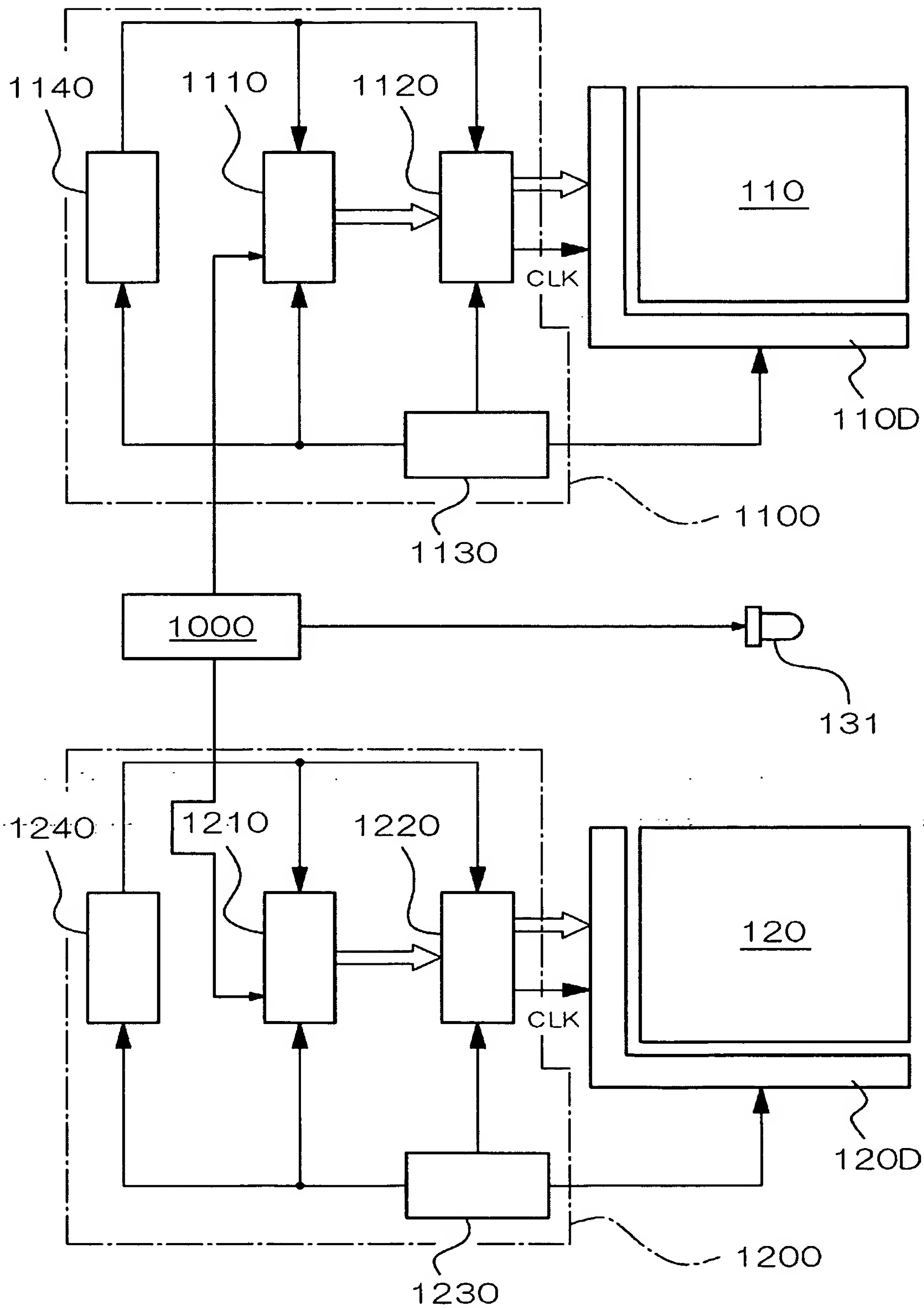


(a)



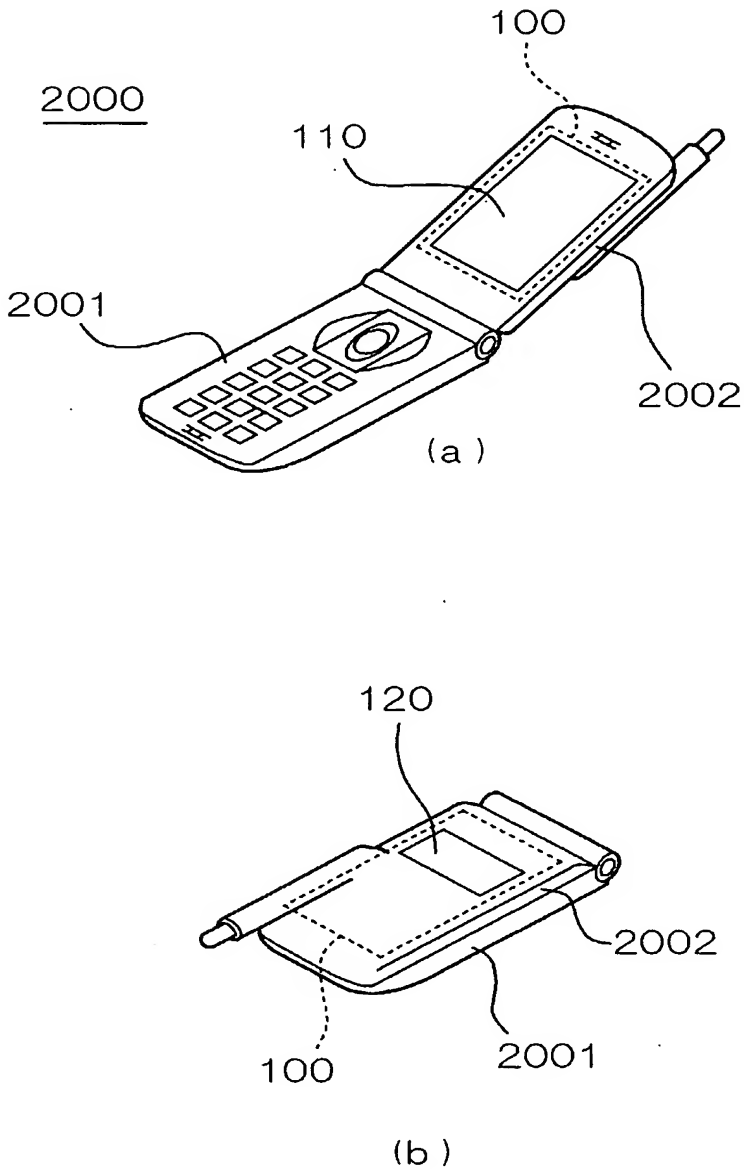
(b)

[FIG. 6]



1140
1110
1120
110
CLK
110D
1130
1100
1000
131
1240
1210
1220
120
CLK
120D
1230
1200

[FIG. 7]



[Name of Document] ABSTRACT

[Abstract]

[Object] To provide a display device which offers double-sided display and achieves a thin structure and also which prevents deterioration in display quality of each of front and back display means when an illumination means such as a backlight is shared by these display means.

[Solving Means] A display device 100 includes a first display means 110 having a display surface on the front surface thereof; a second display means 120 having a display surface on the rear surface thereof; and a common illumination means 130 interposed between the first display means and the second display means, for illuminating both the first display means and the second display means with light, wherein the illumination means 130 includes a light-guiding member 132 having a first light-emitting surface 132b opposed to the first display means and a second light-emitting surface 132c opposed to the second display means, and the second light-emitting surface of the light-guiding member and the second display means have a transflection means 141 interposed therebetween.

[Selected Figure] Fig. 1